Vagueness and the tradeoff between the classification and delineation of geographic regions

Thomas Bittner
Departments of Philosophy and Geography
National Center for Geographic Information and Analysis (NCGIA)
State University of New York at Buffalo
bittner3@buffalo.edu

Overview

- Methodological background: skepticism about objectivity and rigor in geography
- Ecoregion classification and delineation as a case study
- Vagueness and the tradeoff between the classification and delineation of ecoregions
- Conclusions

The controversy about the possibility of the fromalization of regional classification systems

Is it possible to 'formalize' geography?

Bunge: yes!!

"geography is a science which has to be pursued through the organization of facts into theories"

Bowker, Wateron: no!!

skepticism about the possibility of objective, logically rigorous, non-local, and temporally stable classification and delineation systems for geo-regions

logical theories = ontologies

"There is in geography, as in any other science, a continuous interplay of logic, theory and fact (description). One cannot be separated from the other...
Geography is the science of locations. Regional geography classifies locations and theoretical geography predicts them ..."

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Theoretical geography

... continuous interplay of logic, theory and fact (description)

Formal ontology

a sub-field of philosophy, which studies the interplay of logic, theory and fact in the context of very general categories.

provides foundations

Applied ontology

applies formal ontological principles to the development of formal theories in **specific domains** and to the **design of information systems**.

Theoretical geography

... continuous interplay of logic, theory and fact (description)

Formal ontology

a sub-field of philosophy, which studies the interplay of logic, theory and fact in the context of very general categories.

- basic categories
- relations between categories
- logical properties thereof

Basic categories and relations

Universals

Particulars
- independent (Tom Bittner)
- dependent (Tom's weight, Tom's life)

Collections

Basic categories and relations

Universals

Particulars
- independent endurants
- dependent qualities, perdurants

Collections

Basic categories and relations

Universals
- Endurant universals (Human Being)
- Quality universals (Weight)
- Perdurant universals (Human Life)

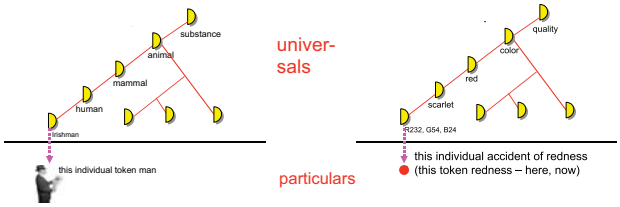
Particulars
- independent endurants
- dependent qualities, perdurants

Collections

Universals group particulars in restricted ways: form tree structures

Of **independent** endurants

Of **dependent** endurants



Basic categories and relations

Universals
- Endurant universals (Human Being)
- Quality universals (Weight)
- Perdurant universals (Human Life)

Particulars
- independent endurants
- dependent qualities, perdurants

Collections

Group particulars in arbitrary, set-like ways.

Basic categories and **relations**

Endurant Universals

Endurant Individuals

i-part-of

Bunge's 'geometry'

Collections of endurant individuals

Basic categories and **relations**

Endurant Universals

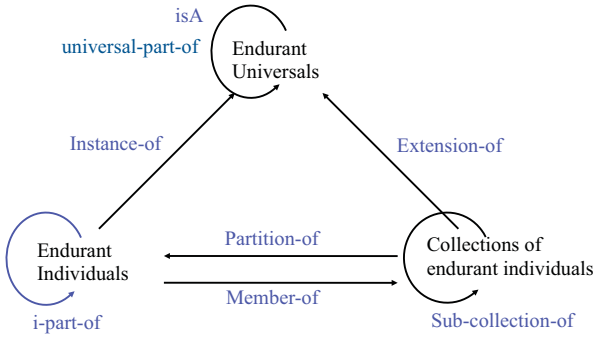
Endurant Individuals

i-part-of

Egenhofer's 9-intersection

Collections of endurant individuals

Basic categories and **relations**



RELATION TO TIME / GRANULARITY	ENDURANT				OCCURRENT
	INDEPENDENT		DEPENDENT		

RELATION TO TIME / GRANULARITY	ENDURANT				OCCURRENT
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GEOGRAPHIC SCALE					
ORGANISM SCALE					
CELLULAR SCALE					
MOLECULAR SCALE					

RELATION TO TIME / GRANULARITY	ENDURANT				OCCURRENT
	INDEPENDENT		DEPENDENT		
GEOGRAPHIC SCALE					
ORGANISM SCALE	Open Biological Ontologies (OBO) Artifact ontologies Ontologies of organizations ...				
CELLULAR SCALE					
MOLECULAR SCALE					

RELATION TO TIME / GRANULARITY	ENDURANT				OCCURRENT
	INDEPENDENT		DEPENDENT		
GEOGRAPHIC SCALE	Theoretical geography ... continuous interplay of logic, theory and fact (description)				
ORGANISM SCALE	As an **integrated** component of a larger **system of ontologies**				
CELLULAR SCALE					
MOLECULAR SCALE					

Theoretical geography

... continuous interplay of logic, theory and fact (description)

•... Geography is the science of locations.
•Regional geography classifies locations
•theoretical geography predicts them

↔

Applied ontology

applies formal ontological principles to the development of formal theories in **specific domains** and to the **design of information systems**.

Theoretical geography

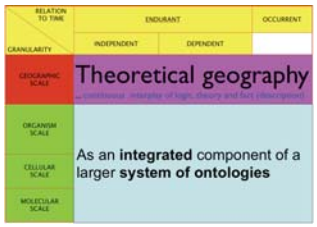
... continuous interplay of logic, theory and fact (description)

•... Geography is the science of locations. ↔ Logical theory of location
•Regional geography classifies locations ↔ Classification of location
•theoretical geography predicts them ... ↔ Reasoning about (change of) location

Is it possible to 'formalize' geography?

Bunge: yes!!!

"geography is a science which has to be pursued through the organization of facts into theories"



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Bowker, Wateron:

skepticism about the possibility of objective, logically rigorous, non-local, and temporally stable classification and delineation systems for geo-regions

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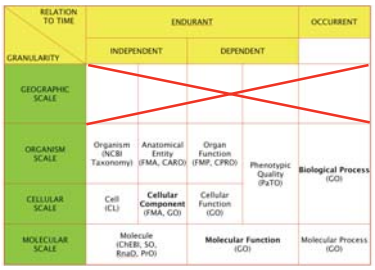

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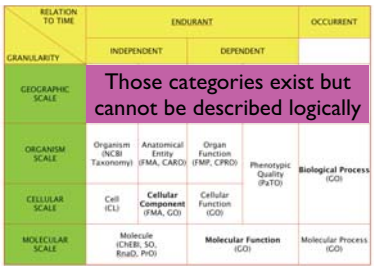

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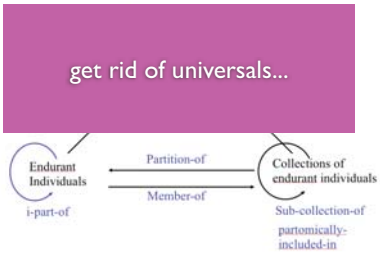

skepticism about the possibility of objective, logically rigorous, non-local, and **temporally stable** classification and delineation systems for geo-regions

there are no laws that govern change over time (change is chaotic)

the laws that govern change over time are too difficult to understand/formalize

skepticism about the possibility of objective, logically rigorous, non-local, and temporally stable classification and delineation systems for geo-regions

If you are a skeptic you need to be explicit about what you are skeptical about.

skepticism about the possibility of objective, logically rigorous, non-local, and temporally stable classification and delineation systems for geo-regions

there is no help ...

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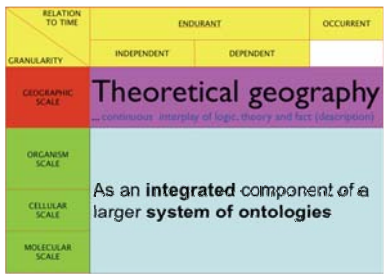

this can be addressed but it is more complicated than Bunge thought ...

... but ontology can help!!

What makes geography so hard?

phenomena of geographic scale are **granular** in nature, and subject to **vagueness** and **change** over time

Ontological aspects

- nature of
  - granularity (what does homogeneity mean)
  - vagueness (what **IS** a mountain)
  - change

Epistemic aspects

- limits of human knowledge
  - *how to* **classify** geographic phenomena (how to classify mountains, eco-regions, ...)
  - *how to* **delineate** geographic phenomena (uncertainty of boundary location)
  - *how to* **keep track** of change

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Epistemic aspects

Claire Waterton
From Field to Fantasy:
Classifying Nature, Constructing Europe

Ontological Instability

•limits of human knowledge
  •*how to* **classify** geographic phenomena (how to classify mountains, eco-regions, ...)
  •*how to* **delineate** geographic phenomena (uncertainty of boundary location)
  •*how to* **keep track** of change

What makes geography so hard?

phenomena of geographic scale are **granular** in nature and subject to **vagueness** and **change** over time

Ontological aspects ↔ Epistemic aspects
confusion
lack of formal rigor

•more powerful logical frameworks are needed
  •to deal with granularity, vagueness, and change
  •to make explicit epistemic aspects (logics of belief)

Today these aspects are often lumped together using fuzzy logic and/or statistical techniques

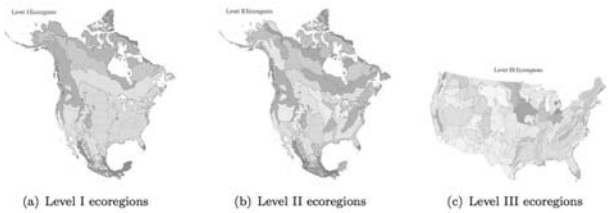
What makes geography so hard?

phenomena of geographic scale are **granular** in nature and subject to **vagueness** and **change** over time

Ontological aspects ↔ Epistemic aspects
confusion
lack of formal rigor

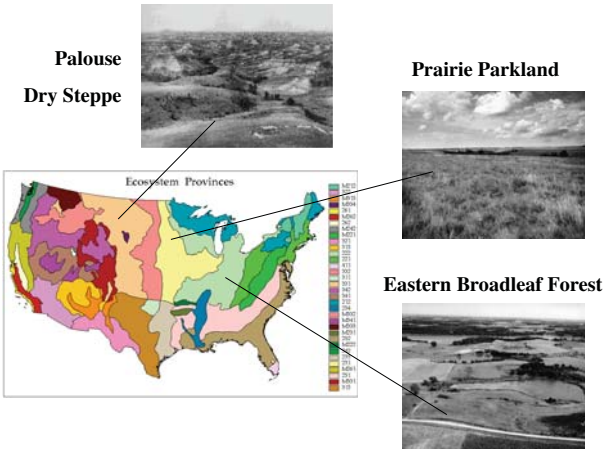
skepticism about the **possibility** of objective, logically rigorous, non-local, and temporally stable classification and delineation systems for ecoregions, ecosystems, biomes, biotopes

Ecoregion classifications as a case study



(a) Level I ecoregions (b) Level II ecoregions (c) Level III ecoregions

Figure 1. Ecoregions of North America (EPA) at different scales (EPA 2007)



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Bailey & Omernik Ecoregion classification & delineation

Bowker, Wateron:

skepticism about the possibility of objective, logically rigorous, non-local, and temporally stable classification and delineation systems for geo-regions

Ecoregion classification and delineation

Bailey:

non-local, classification **and** delineation systems for eco-regions are possible

Omernik:

skepticism about the possibility of **non-local**, classification systems for eco-regions

thinks delineation systems are possible

Ecoregion classification and delineation

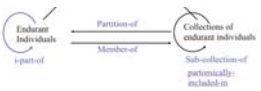
Bailey:

Aristotelean method of classification

Classification **and** delineation system

Omernik:

weight-of-evidence methodology

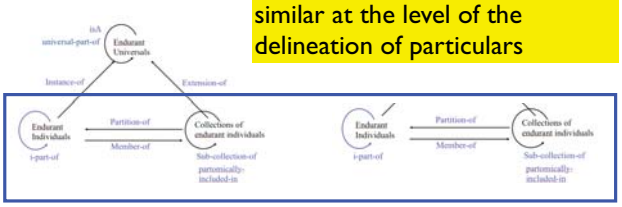


delineation system

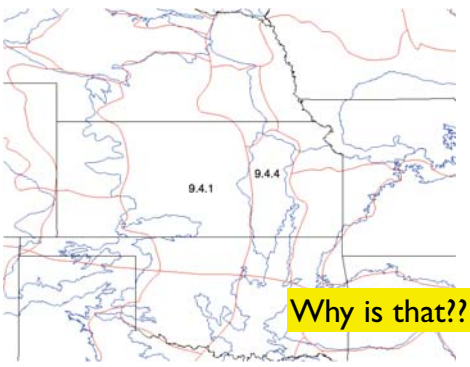
Ecoregion classification and delineation

Bailey:

•Both, believe that there are objective ways to delineate ecoregions
•Both systems are somewhat similar at the level of the delineation of particulars



Ecoregion delineation: Bailey red, Omernik blue



Why is that???

Do you see similarities?

delineate similar ecoregions

Do you see differences?

Omernik's boundaries are much more fine-grained

How to delineate ecoregions?

Palouse

Dry Steppe

Prairie Parkland

Find common and distinguishing properties/qualities:

- climate
- land form
- (climax) vegetation
- soil types
- etc.

Eastern Broadleaf Forest

How to delineate ecoregions?

Palouse

Dry Steppe

hilly

Prairie Parkland

Find common and distinguishing properties/qualities:

- climate
- land form
- (climax) vegetation
- soil types
- etc.

flat

flat

Eastern Broadleaf Forest

How to delineate ecoregions?

Palouse

Dry Steppe

no vegetation

Prairie Parkland

Find common and distinguishing properties/qualities:

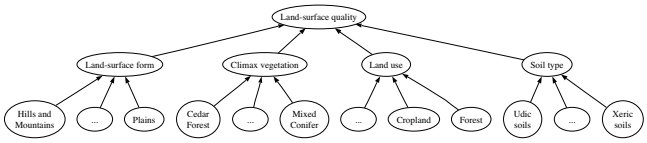
- climate
- land form
- (climax) vegetation
- soil types
- etc.

grass

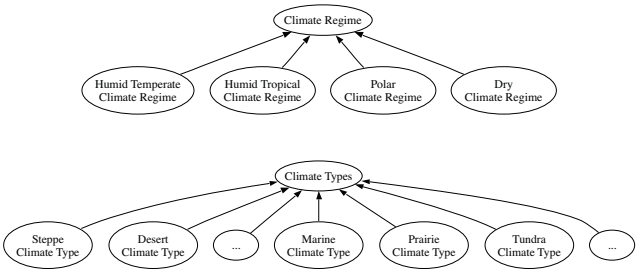
gras + trees

Eastern Broadleaf Forest

Ecoregion qualities (land-surface)



Ecoregion qualities (climate)



Ecoregion delineation

Terrestrial region	*Land-surface form*	*Climax vegetation*	*Land use*	*Soil type*
...	...	...	...	...
Central Great Plains	Irregular plains	Bluestem / grama prairie, bluesteam prairie, buffalo grass	Cropland, cropland with grazing land, some irrigated agriculture	Dry Mollisols
Flint Hills	Open Hills	Bluestem prairie (bluesteam, panic indian grass)	Subhumid grassland and semiarid grazing land	Mollisols (Hapludolls)
...	...	...	...	...

Table 3. Land-surface qualities of terrestrial regions – Central Great Plains as an example (Omernik 1987, Table 1)

Central Great Plains

Ecoregion delineation

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...	...	...	...	...

Table 3. Land-surface qualities of terrestrial regions – Central Great Plains as an example (Omernik 1987, Table 1)

Flint Hills

Ecoregion classification and delineation

The terrestrial region Central Great Plains is characterized by patterns of qualities

Terrestrial region	*Land-surface form*	*Climax vegetation*	*Land use*	*Soil type*
...	...	...	...	...
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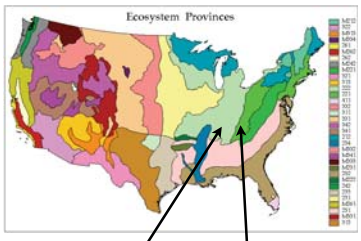


Q1,...,Qn P1,...,Pn

At least one pair of qualities must be **distinct**.
The boundary is where there are **inhomogeneities** in quality distributions

Ecoregion delineation

Problems with homogeneity and inhomogeneity of quality distribution

Scale dependency granularity vagueness

Ecoregion delineation

Scale dependency

- *Irregular plains* has no instance that characterizes a terrestrial region smaller than geographic scale.
- *Irregular plains* has no instance that characterizes a terrestrial region of continental scale.

Ecoregion delineation

granularity

- The terrestrial region Central Great Plains is characterized by the land-surface form Irregular plains.
- This does not mean that every part of geographic scale of this region has a land-surface form Irregular plains.
- There may be *comparatively small* (geographic-scale) regions in which *different* land-surface forms are instantiated.

Homogeneity with respect to quality pattern

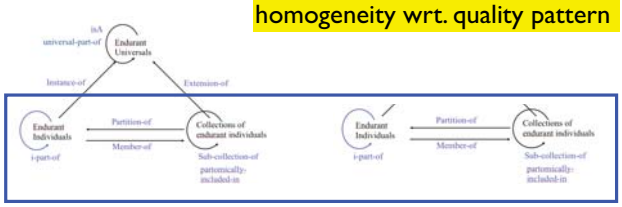
A terrestrial region x is homogeneous with respect to the quality pattern QP=<Q1,...,Qn> if and only if

- x is of at least of geographic scale and
- the sum of all parts of x that are
  - terrestrial regions of geographic scale and
  - that do not have qualities Q1 ... Qn
  - is negligible in size with respect to the size of x.

Ecoregion classification and delineation

Bailey:

•Both, believe that there are objective ways to characterize ecoregions in terms of homogeneity wrt. quality pattern



homogeneity wrt. quality pattern

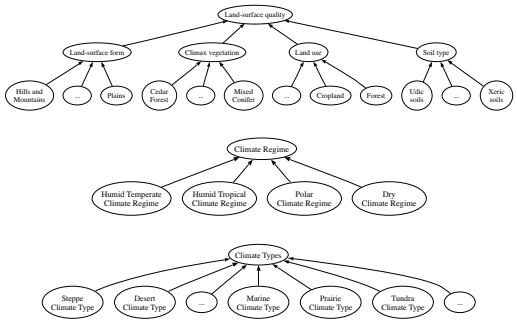
Bailey:

•ecoregion universals can be defined in terms of quality pattern
• the classification determines the delineation

Omernik:

• quality pattern are sufficient for delineation
• Boundaries are where there are inhomogeneities between quality pattern
•no ecoregion classification

Bailey's classification

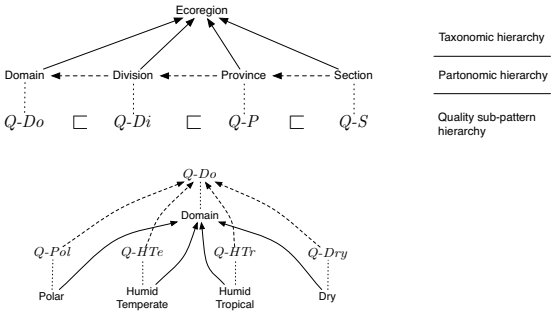


Bailey's classification

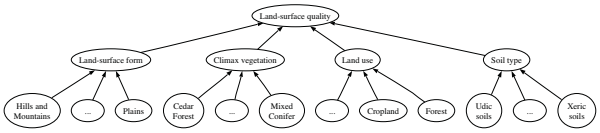
quality pattern type	symbol	constituting quality universals
Land-surface	*Q-L*	*<Land-surface form, Climax Plant Formation, Land use, Soil type>*
Climate	*Q-Do*	*<Climate regime>*
	Q-Di	*<Climate regime, Climate type, Elevation>*
	Q-P	*<Climate regime, Climate type, Elevation, Climax Vegetation>*
Climate + Land-surface	*Q-S*	*<Climate regime, Climate type, Elevation, Climax Vegetation, Land-surface form, Land use, Soil type>*

Table 4. Genus quality pattern.

Bailey's classification



Omernic's delineation



• quality pattern are sufficient for delineation
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Omernic's delineation

Terrestrial region	Quality pattern
...	...
Central Great Plains	...are slightly lower, receive more precipitation, and are somewhat more irregular than the Western High Plains to the west ... Once a grassland, with scattered low trees and shrubs in the south, much of this ecological region is now cropland ...
Flint Hills	rolling hills with relatively narrow steep valleys ... composed of shale and cherty limestone with rocky soils ... the western edge of the tallgrass prairie ... In contrast to surrounding ecological regions that are mostly in cropland, most of the Flint Hills region is grazed by beef cattle ...
...	...

Table 6. Qualities of two members of the collection *LIII* ecoregions (EPA 2002)

Quality pattern are VERY specific, defined wrt. neighbors

Omernic's delineation

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...	...

Table 6. Qualities of two members of the collection *LIII* ecoregions (EPA 2002)

includes historical qualities

homogeneity wrt. quality pattern

Bailey:

•ecoregion universals can be defined in terms of rather general quality pattern

Omernik:

• Only very specific quality pattern are sufficient for delineation
• Boundaries are where there are inhomogeneities between quality pattern

yes

no

Ecoregion classification in terms of qualities

Ecoregion classification and delineation

Bailey:

non-local, classification and delineation systems for eco-regions are possible

Omernik:

skepticism about the possibility of **non-local**, classification and delineation systems for eco-regions

Ecoregion delineation: Bailey red, Omernik blue

delineate similar ecoregions

Omernik's boundaries are much more fine-grained

Vagueness, delineation, and classification

we need to understand the fundamental trade-off between

the degree to which inherently vague ecoregions can be described in a unified classification system

Classification but coarse delineation

the possible degree of preciseness of the delineation of ecoregion particulars.

relatively precise delineation but no classification

Fundamental sources of vagueness

homogeneity with respect to quality pattern

... inhomogeneities are negligible in size ...

vague

Instantiation of quality particulars at geographic regions

It is subject to vagueness whether or not a particular quality instantiates a given universal

Fundamental sources of vagueness

Terrestrial region	*Land-surface form*	*Climax vegetation*	*Land use*	*Soil type*
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... inhomogeneities are negligible in size ...

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Conclusions

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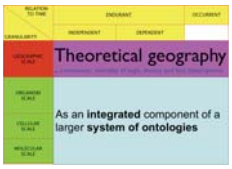

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Instantiation of quality particulars at geographic regions

It is subject to vagueness whether or not a particular quality instantiates a given universal

skepticism about the possibility of objective, logically rigorous, non-local, and temporally stable classification and delineation systems for geo-regions

If you are a skeptic then you need to be explicit about what you are skeptical about...

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... there may be good reasons to be skeptical about certain aspects ...

↓

... because geography is complicated